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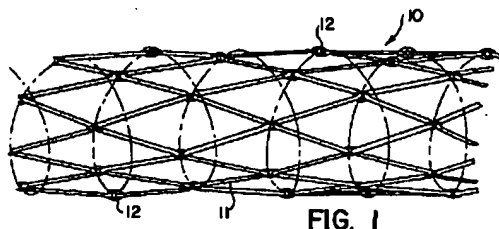
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⑤④ **Intraluminal stent.**

⑤⑦ An intraluminal stent (10) includes a continuous helix of zig-zag wire (11) and loops (12) which connect adjacent apices of the wire. The stent is compressible and self-expandable substantially to a pre-compressed configuration. A method of forming the stent includes bending a length of wire into a zig-zag configuration and a helix and connecting adjacent apices of the wire. A method implanting this stent includes compressing the stent radially, implanting it in a predetermined location of a body vessel, and allowing it to recoil to the configuration it had before compression.



**FIG. 1**

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## BACKGROUND OF THE INVENTION

### Field Of The Invention

The present invention generally relates to a vascular prosthesis, and more particularly to an intraluminal stent which has a flexible and elastic tubular construction with sufficient hoop strength to prevent elastic recoil of balloon-resistant strictures or to produce delayed dilation of those strictures.

### Description Of The Prior Art

The prior art includes a wide variety of intraluminal stents and grafts. For example, Palmaz U.S. Patent No. 4,733,665 discloses a balloon-expandable intraluminal graft, including an embodiment comprising a wire mesh tube. Intersecting wire members, secured to one another at their intersections by welding, soldering or gluing, form the wire mesh and define a diamond-like pattern. This structure provides a relatively high resistance to radial collapse; but it suffers a number of disadvantages. First it is a rigid structure which cannot easily assume the configuration of a curved vessel which receives it. Second one must use a balloon catheter to expand and implant it. This requirement limits the length of the graft, as does the rigidity.

Other prior stents have more flexible constructions; but they suffer other disadvantages. Wiktor U.S. Patent No. 4,886,062, for example, discloses a stent which has a relatively flexible construction. This construction includes a deformable wire bent into a zig-zag design and coiled in a spiral fashion. The resulting wire tube has an open configuration with a reduced hoop strength. Each hoop lies essentially isolated from the adjacent hoops and does not obtain substantial support from them. Moreover, the open configuration increases the risk that plaque elements may herniate through the coil. Finally, one must use a balloon catheter to expand and implant it. Thus, the length of the stent cannot exceed the balloon length of available balloon catheters.

The intraluminal stent of the present invention avoids the disadvantages of the prior art stents and grafts. It has sufficient hoop strength to prevent elastic recoil of balloon-resistant strictures. The stent of the present invention has a flexible construction which allows it to follow the curvature of the vessel which receives it. It has an elastic construction which allows implantation without a balloon catheter. This elasticity further allows compression of the structure and recoil upon implantation to produce delayed dilation of the receiving vessel.

## SUMMARY OF THE INVENTION

In accordance with an embodiment of the present invention, an intraluminal stent includes a predetermined length of wire having a sinuous or zig-zag configuration and defining a continuous helix with a plurality of connected spirals or hoops. A plurality of loop members connect adjacent apices of adjacent helix hoops. The stent is compressible and self-expandable substantially to the configuration prior to compression.

In accordance with an alternative embodiment of the present invention, an intraluminal stent includes the continuous helix and the plurality of loop members described above. It also includes a prosthetic graft disposed longitudinally of the wire helix within its central opening (or around the wire helix). One or more of the loop members secures the graft to the wire helix. This graft is a flexible, tubular shell which allows the wire helix to contract and recoil.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of this invention one should now refer to the embodiments illustrated in greater detail in the accompanying drawings and described below by way of examples of the invention. In the drawings:

FIG. 1 is a perspective view of the intraluminal stent of the present invention;

FIGS. 2-4 are side elevation views of a suture connection for the stent of FIG. 1;

FIG. 5 is a sectional view of the devices used to implant the stent of FIG. 1;

FIG. 6 is a sectional view of the sheath and catheter devices used to implant the stent, showing the catheter holding the stent in place as the sheath moves out of the body vessel.

FIG. 7 is a side elevation view of an alternative embodiment of the stent of the present invention;

FIG. 8 is a sectional view taken along the line 8-8 in FIG. 7;

FIG. 9 is a partial perspective view of the stent of FIG. 7, showing a suture connection for the stent; and

FIG. 10 is a perspective view of the mandrel used to form the wire helix of the present invention.

While the applicant will describe the invention in connection with preferred and alternative embodiments, one should understand that the invention is not limited to those embodiments. Furthermore, one should understand that the drawings are not necessarily to scale. In certain instances, the applicant may have omitted details which are not necessary for an understanding of the present in-

vention.

#### DETAILED DESCRIPTION OF THE DRAWINGS

Turning now to the drawings, FIG. 1 shows the intraluminal stent of the present invention generally at 10. This stent includes a wire body 11 made out of a predetermined length of wire having a sinuous or zig-zag configuration and defining a continuous helix with a series of connected spirals or hoops. It also includes loop members 12 which connect adjacent apices of adjacent helix hoops to help define the tubular stent. The loop members 12 may connect all or some of the pairs of adjacent apices.

The wire body 11 is an elastic alloy which provides radial elasticity for the stent. Preferably, it is a nitinol alloy which has superior elasticity and fatigue resistance. The wire has a round cross-section; but its cross-section may also be any one of a variety of shapes, e.g., triangular, rectangular, etc. Alternatively, any material of sufficient strength and elasticity and the other properties identified above may form the wire body, including stainless steel, tantalum, titanium, or any one of a variety of plastics.

The loop members 12 connect adjacent apices of adjacent hoops of the wire body 11 so that the adjacent apices abut each other (See FIGS. 2-4). Thus, each hoop receives support from adjacent hoops, increasing the hoop strength of the overall stent structure and minimizing the risk of plaque herniation. The loop members 12 are ligatures of suture material with the ends tied together to form a loop. This material is polypropylene material or any other biocompatible material of sufficient strength. Although sutures are the preferred connecting means, other connecting means such as staples and rings made of metal or plastic may provide the same function.

The stent structure of the present invention allows compression prior to implantation in a human or animal vessel. After implantation, upon release of the compressive force, the stent structure recoils (or self-expands) to its original configuration. Thus, it continues to provide dilating force in the implanted state. The structure provides flexibility which allows the stent to follow the curvature of the vessel which receives it.

Turning now to FIGS. 7-9, an alternative embodiment of the present invention includes the wire body and suture connections described above. This alternative also includes a prosthetic graft 13 disposed inside the central opening of the wire body. The graft 13 is a round, open tube made of polytetrafluoroethylene (PTFE), dacron or any other suitable biocompatible material. It has an outside diameter slightly smaller than the inside diameter of the wire body 11. One or more hoop members

connect the graft 13 to the wire body 11 as shown in FIG. 9. In place, the graft closes the diamond shaped openings of the stent structure to further minimize plaque herniation and minimize the flow of fluid and cellular elements through the structure.

Alternatively, the graft 13 may lie around the outside of the wire helix. Furthermore, the graft 13 may be co-extensive with the wire helix; or it may be shorter than the wire helix. Finally, the graft 13 may include a plurality of segments disposed within the wire helix or around the outside of the helix.

The method of making the stent of the present invention includes bending a predetermined length of wire in a zig-zag fashion between the pins 14 of the mandrel 15 and around the mandrel, thus forming a helix (See FIG. 10). The next step includes removing the helix from the mandrel by removing the pins and sliding the helix off the mandrel. The process further includes connecting adjacent apices of adjacent helix hoops. A fabricator makes each connection by placing a ligature of suture material (or any other suitable material) around the wire segments which define two adjacent apices and tying the ends of the ligature together to form a loop. In applications in which the wire body is nitinol wire, the process includes securing the ends of the wire to the mandrel and annealing the wire to a predetermined temperature (and thus imparting a thermal memory for the annealed shape) before removing the helix from the mandrel.

The method of implanting the stent of the present invention includes compressing it and placing it into the central bore of an introducing device 16. The next step includes coupling the device 16 with the hub 17 of a sheath 18 which extends to the implantation location. The next step involves using a catheter 19 to push the compressed stent to the predetermined location and to hold the stent at the location with the catheter, and then removing the sheath. The final step involves removal of the catheter to allow the stent to recoil.

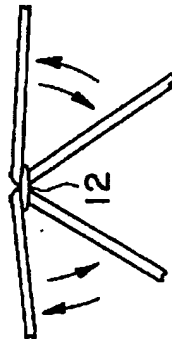
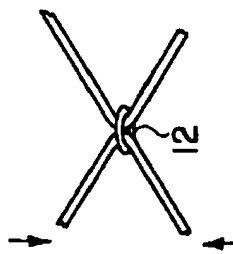
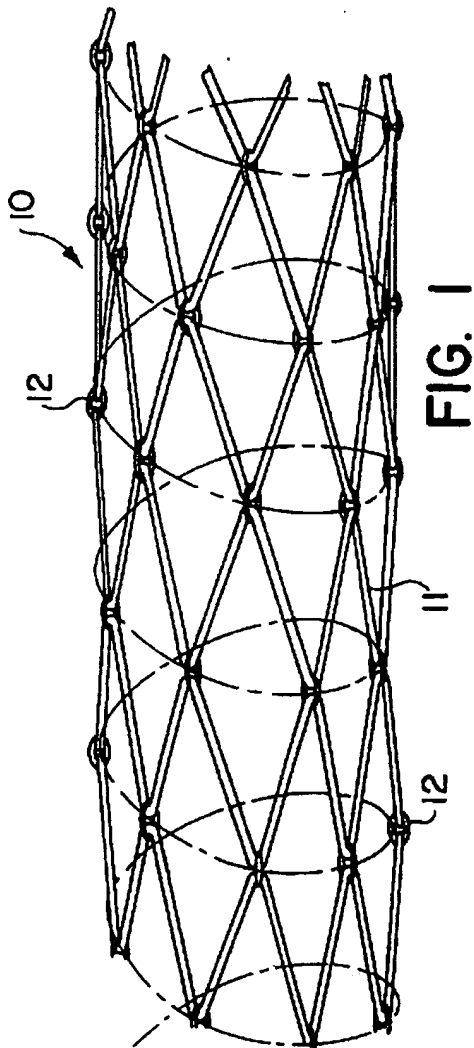
In applications in which the wire body is a nitinol metal, a user reduces the diameter of the stent by first cooling it, e.g., by submerging it in ice water. This cooling places the nitinol in a martensitic phase and facilitates manual reduction of the diameter and insertion of the stent in the central bore of the device 16. The device 16 and the sheath 18 restrain the stent until deployment in a predetermined location. At that location in a subject's body, body fluids warm the nitinol and place it in an austenitic phase which is the stable phase of this metal and which corresponds to a fully opened or expanded configuration of the stent (to its original annealed diameter).

While the above description and the drawings illustrate one embodiment and an alternative, one should understand, of course, that the invention is

not limited to those embodiments. Those skilled in the art to which the invention pertains may make other modifications and other embodiments employing the principals of this invention, particularly upon considering the foregoing teachings. For example, one may use a deformable material to construct the wire body 11 of the stent and then use a balloon catheter to deploy it. The applicant, therefore, by the appended claims, intends to cover any modifications and other embodiments which incorporate those features which constitute the essential features of this invention.

### Claims

1. An intraluminal stent comprising: a predetermined length of elastic wire having a zig-zag configuration and defining a continuous helix with a plurality of hoops; a plurality of loop members for connecting adjacent apices of adjacent helix hoops; the stent being compressible and self-expandable substantially to a pre-compressed configuration. 5
2. The stent of claim 1, wherein the loop members connect the adjacent apices of the helix hoops in abutting relation. 10
3. The stent of claim 1, wherein the elastic wire is a high shape memory nitinol alloy. 15
4. The stent of claim 1, wherein the loop members have a substantially greater flexibility than the wire. 20
5. The stent of claim 4, wherein each loop member includes a single ligature of suture material tied into a loop. 25
6. The stent of claim 5, wherein the suture material is made of polypropylene. 30
7. The stent of claim 1, further comprising a tubular graft member secured to the wire helix with at least one of the loop members. 35
8. The stent of claim 7, wherein the graft member lies within the wire helix. 40
9. The stent of claim 6, wherein the plurality of the loop members extend around adjacent apices of wire, into the graft member through openings in the graft member and out of the graft member through other openings. 45
10. The stent of claim 9, wherein the graft member is a tube of polytetrafluoroethylene. 50
11. A method of implanting a tubular intraluminal stent which is radially compressible and elastic using a tubular sheath disposed between an entry location in a body and the location of implantation and a catheter, said method comprising the steps of: compressing the stent; inserting the compressed stent into the tubular sheath at the entry location; pushing the compressed stent through the sheath to the implantation location using the catheter; and withdrawing the sheath while holding the stent at the implantation location with the catheter. 55
12. A method of forming a tubular intraluminal stent comprising: bending a predetermined length of wire into a sinuous configuration and simultaneously into a helix of predetermined diameter and length; connecting together a plurality of adjacent apices of adjacent helix hoops to define the stent. 60



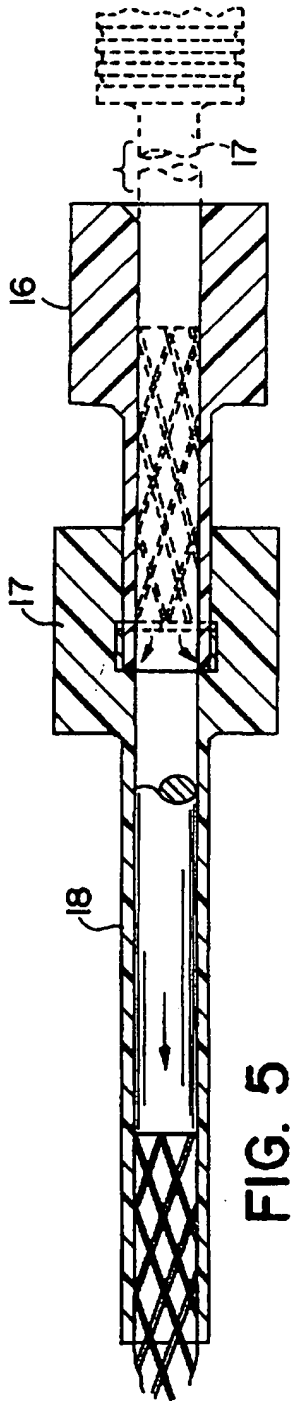


FIG. 5

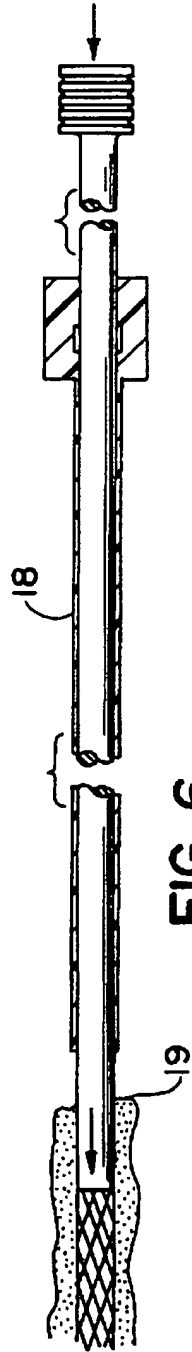


FIG. 6

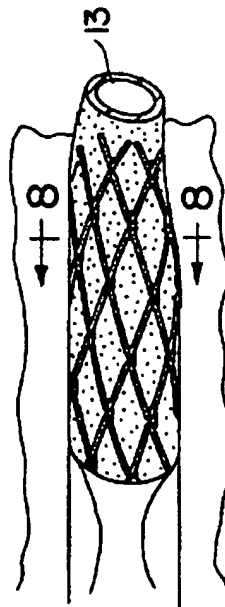


FIG. 7

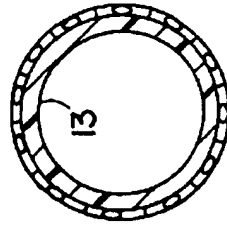


FIG. 8

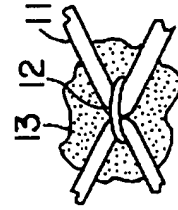


FIG. 9

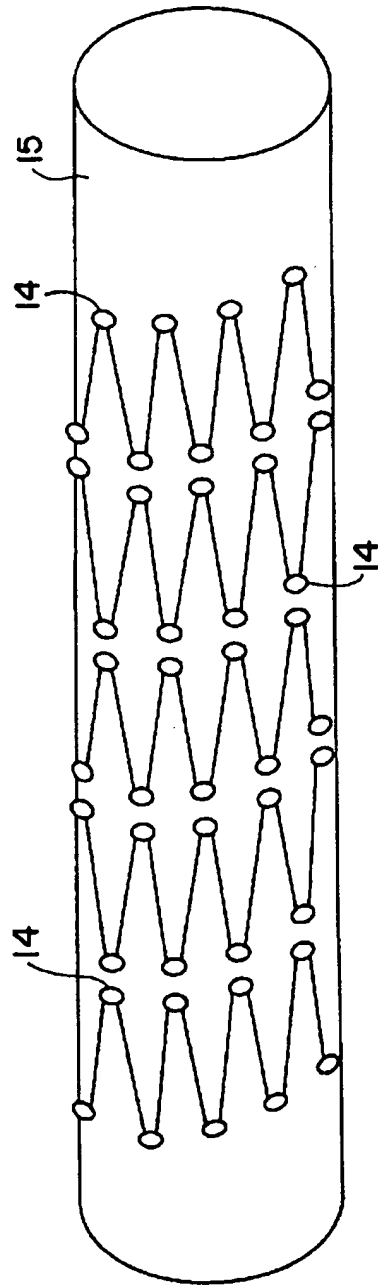


FIG. 10



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# EUROPEAN SEARCH REPORT

Application Number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 93102673.6
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
X	<u>WO - A - 92/00 043</u> (SCHNEIDER) * Totality; especially page 5, line 12 - page 19, line 3; fig. 11 *	1,6, 11,12	A 61 F 2/06 A 61 M 29/00
Y	--	7,8,10	
A	<u>US - A - 5 078 736</u> (BEHL) * Claims 1-3,18,20,21,22; column 7, lines 8-29; fig. 1-11 *	1,11	
Y	<u>US - A - 4 306 318</u> (MANO et al.) * Totality *	7,8,10	
A	<u>WO - A - 91/07 928</u> (ROTMANN) * Totality *	1,3,11	
			TECHNICAL FIELDS SEARCHED (Int. CL.5)
			A 61 F A 61 M
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 27-05-1993	Examiner MIHATSEK
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	